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The Impact of Musical Experience on Second Language Processing: Postprint

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Date: 2023-10-09T00:00:00+00:00

Abstract

Research on the relationship between music and language has attracted considerable attention in recent years. Evidence from behavioral and cognitive neuroscience further indicates that musical experience can transfer across domains to second language acquisition, facilitating second language processing in comprehension, production, and learning. The underlying mechanism of this transfer effect is realized through two pathways: enhancing the processing of shared acoustic cues between music and language, and enhancing individuals' general cognitive processing abilities. On this basis, future research can pursue in-depth investigations from multiple perspectives to clarify the influences of musical experience and musical aptitude on second language processing, and to compare the connections and distinctions between how musical experience affects native versus second language processing.

Full Text

The Effect of Musical Experience on Second Language Processing

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Abstract

The relationship between music and language has attracted widespread attention in recent years. Behavioral and cognitive neuroscience evidence further demonstrates that musical experience can transfer across domains to second language acquisition, facilitating second language processing in three aspects: comprehension, production, and learning. This transfer effect is achieved through two internal mechanisms: promoting the processing of shared acoustic cues in music and language, and enhancing individuals' general cognitive processing

abilities. Building on this foundation, future research can conduct in-depth exploration from multiple perspectives to clarify the influence of musical experience and musical aptitude on second language processing, and compare the connections and distinctions between the effects of musical experience on native language versus second language processing.

Keywords: musical experience, second language, language comprehension, language production, language learning

Introduction

Music and language, as two distinct symbolic systems unique to humans, share intrinsic connections in structural organization, cognitive processing, and neural mechanisms despite differences in constituent elements (e.g., intervals and chords in music versus vowels and consonants in language). Both are based on acoustic signals that form melody and rhythm, and both employ hierarchical organization to combine discrete small units into larger meaningful ones. Music and language also overlap in cognitive and neural mechanisms for syntactic processing, semantic processing, and detecting subtle emotions conveyed through acoustic signals.

Given that musical experience has been shown to positively influence native language acquisition and development, an important question arises: what role does music play in second language development? Researchers have employed behavioral and cognitive neuroscience techniques to investigate the effects of musical experience on second language comprehension, production, and learning. This paper reviews relevant research on how musical experience influences second language processing, analyzes the underlying mechanisms, and concludes with considerations and prospects for future research.

1. Effects of Musical Experience on Second Language Comprehension

Language comprehension involves the projection from speech and text to meaning. Existing studies have found that musical experience affects second language comprehension primarily in two aspects: speech perception and lexical access.

1.1 Speech Perception

Speech perception is the process by which listeners extract acoustic-phonetic information from continuous speech streams and convert it into speech signals. Speech information consists of segmental and suprasegmental features. Segmental features comprise vowels and consonants, while suprasegmental features include phonetic properties of vowels and consonants that extend beyond individual sounds, often spanning syllables, words, or phrases.

Researchers have first examined the impact of musical experience on second language segmental perception. When processing a second language, learners are

affected by negative transfer from their native language segmental features. For example, because Japanese lacks the phonemic contrast /r/-/l/, Japanese speakers have difficulty distinguishing between these sounds. Fortunately, musical training can mitigate this negative transfer effect and improve second language proficiency to some extent. Behavioral and event-related potential (ERP) studies have found that musicians show higher accuracy in second language phoneme discrimination tasks and exhibit larger N200 amplitudes reflecting speech categorization, indicating that musical training enhances phoneme perception abilities. Longitudinal studies have also shown that musical training, like phonetic training, facilitates the development of second language phonological awareness in children. However, research on which type of musical training promotes phonological awareness development has yielded mixed results. While some studies found that rhythm training improves phonological awareness in children with dyslexia, others found that only pitch training, not rhythm training, showed such effects. These discrepancies may be due to differences in participant populations, as typically developing children may have stronger phonological awareness that is more difficult to enhance compared to children with reading difficulties.

The facilitative effect of musical experience on second language perception extends beyond segmental features to suprasegmental features. Studies have shown that musical training can promote non-tonal language speakers'processing of lexical tones. For instance, research recording brainstem frequency-following responses (FFRs) found that musicians have superior ability to represent pitch contours of different tones compared to non-musicians. Musical experience also facilitates the segmentation of artificial languages, with both behavioral and electrophysiological results showing that musically trained adults and children outperform control groups in speech segmentation tasks. Further analysis of continuous EEG signals during learning revealed different brain dynamic patterns: musicians showed an inverted U-shaped learning curve while controls showed a linear curve, indicating distinct neural processes during learning.

When a particular prosodic feature does not exist in the native language, does musical experience still play a role? Kolinsky et al. (2009) used pseudowords adapted from English words (which have variable stress positions and lexical stress) to investigate whether musical experience affects French native speakers' (whose language has fixed stress positions and no lexical stress) processing of lexical stress through a serial repetition task. The results showed that musicians still outperformed non-musicians in lexical stress discrimination. Additionally, musical training has been found to promote non-tonal language speakers' processing of lexical tones, with musically trained individuals showing better performance in tone discrimination tasks.

1.2 Lexical Access

Lexical access, also known as word comprehension, refers to the process by which individuals receive orthographic or phonological input and interpret word meaning. Does musical experience affect lexical comprehension ability? Swaminathan

and Gopinath (2013) used vocabulary subtest scores from the Indian Malin' s Intelligence Scale for Children as an indicator of lexical comprehension ability and examined the relationship between English vocabulary comprehension and musical experience in Indian primary school children. The results showed that the music experience group significantly outperformed the control group on vocabulary tests.

Integrating seen letters with heard sounds is crucial for understanding English vocabulary, but Chinese native speakers do not automatically integrate letters and sounds like English native speakers when reading English. Based on evidence that musical experience positively affects audiovisual coordination, Wang et al. (2020) used a cross-modal mismatch negativity (MMN) paradigm to examine whether musical experience helps Chinese speakers automatically integrate English audiovisual information. The experiment used English letters and their pronunciations as visual and auditory stimuli, respectively, and asked Chinese musicians, Chinese non-musicians, and English native speakers to perform button-press tasks under three conditions (auditory only, simultaneous audiovisual presentation, and delayed auditory presentation) while recording EEG data. The results showed that Chinese musicians, similar to English native speakers, exhibited enhanced cross-modal MMN under both audiovisual conditions, a pattern not observed in Chinese non-musicians, suggesting that musicians can overcome native language constraints to automatically integrate English letter-sound correspondences.

Longitudinal studies provide more robust causal evidence for the relationship between musical experience and second language lexical comprehension. Herrera et al. (2011) selected two groups of 4-5-year-old children, with one group receiving two years of musical training and the other receiving none. Both groups completed a rapid naming task before and after musical training. While both groups showed improvement at post-test, the training group showed significantly greater improvement than the untrained group. However, a subsequent study found no relationship between lexical comprehension ability and musical experience in 4-year-old children, contradicting previous results. The researchers suggested that the six-week training period may have been too short to produce transfer effects.

In summary, researchers using behavioral and cognitive neuroscience techniques have found positive effects of musical training on second language comprehension. However, research on how training type and duration affect second language comprehension remains insufficient, with existing studies showing inconsistent results. Future research should incorporate comparisons of training types and durations to more comprehensively and accurately reveal the transfer effects of musical experience on second language comprehension.

2. Effects of Musical Experience on Second Language Production

Language production is the psychological process of expressing thoughts through language, involving converting ideas into linguistic codes and then into motor commands. Language comprehension and production are distinct psychological processes. Unlike comprehension, language production involves articulatory motor processes and requires integration of feedforward and feedback control in the speech motor system. While language production includes both written and spoken forms, research on musical experience has focused primarily on oral language.

Numerous studies have revealed the influence of musical experience on second language production. Slevc and Miyake (2006) examined Japanese native speakers and investigated the effect of musical experience on second language pronunciation accuracy at word, sentence, and paragraph levels. Hierarchical regression analysis found that individuals' musical experience was a key factor explaining differences in pronunciation accuracy across all three levels.

Further research has explored how musical experience facilitates specific aspects of second language production. Gottfried et al. (2005) found that musical experience helps with lexical tone production, showing that English-speaking musicians were better than non-musicians at producing the four tones of Mandarin Chinese, particularly the fourth tone. Feng et al. (2019) found that musical experience can improve pronunciation accuracy of English lexical stress in Chinese native speakers. Additionally, musical experience can facilitate second language vowel production, with studies showing that musical experience predicts accuracy in second language vowel pronunciation, and even experience with a single song can improve university students' second language pronunciation.

Because language production involves articulatory motor processes, some researchers have found that vocal musical experience may better promote second language production than instrumental experience. Christiner and Reiterer (2013) found that foreign language imitation ability was unrelated to the number of instruments played, but that better singing ability correlated with better imitation ability, manifested in higher accuracy in immediate and post-practice imitation of second language pronunciation. Coumel et al. (2019) used a "fake accent" task requiring German-French bilinguals (German as native language) to speak German with a French accent, rated by native French speakers, and similarly found that second language imitation ability correlated with singing ability.

Since the two most important dimensions of music are pitch and time, which dimension plays a more important role in affecting second language production? Researchers have addressed this question through studies of pronunciation imitation ability. Posedel et al. (2012) found that English native speakers' musical pitch perception ability positively correlated with their ability to imitate Spanish accents, with more accurate pitch judgment associated with higher scores on

accent imitation tests. In contrast, another study found a relationship between musical rhythm perception ability and second language pronunciation imitation ability. Cason et al. (2020) examined French native speakers and found that rhythm ability scores better predicted accuracy in English stress pronunciation than melodic ability. These inconsistent results may be due to differences in the specific dimensions of pronunciation examined: the former focused on segmental (vowel and consonant) pronunciation, which is closely related to pitch perception, while the latter focused on prosodic reproduction, particularly stress pronunciation, which is more strongly associated with rhythm perception.

In summary, besides second language comprehension, musical experience also positively affects second language production. However, most current research on musical experience and second language processing has focused on language comprehension, with studies on second language production still in relatively early stages. Experimental tasks have mostly involved reading aloud or direct imitation of recordings. Future research should further examine the relationship between second language production ability and musical experience in conversational contexts and real-world communication.

3. Effects of Musical Experience on Second Language Learning

Unlike language comprehension and production, language learning is a more complex multidimensional task involving auditory perception and cognitive abilities, requiring the establishment of new semantic or phonological representations and connections with existing knowledge. In language learning research, new word learning and syntactic learning have received extensive attention. Can the effects of musical experience on second language learning be verified at both these levels? Is this transfer effect associated with individual developmental patterns? These questions have generated considerable discussion.

Studies have found that musical experience promotes second language vocabulary learning in children. Good et al. (2015) found that singing helped Spanish children learn English words better, with the singing group outperforming the control group in word recall, vowel pronunciation, and translation tasks. Similar results were confirmed in Dittinger et al. (2017). Additionally, longitudinal studies with children have shown that musical experience can effectively improve the speed and quality of second language vocabulary learning. Busse et al. (2021) divided German primary school students learning French into singing and reading groups for a three-month vocabulary learning program. While both groups showed similar performance before learning, the singing group showed greater gains in French vocabulary after the intervention. Interestingly, only the singing group showed significant positive emotions after each training session, a result consistent with Salcedo' s (2010) pilot study showing that English native speakers learning Spanish words performed better when learning through singing than through speaking.

Carpentier et al. (2016) conducted a 28-day music and French vocabulary learning program with 4-6-year-old children. EEG results based on a passive oddball detection paradigm showed that music training increased diversity in brain network states, supporting the effects of musical experience on brain neuroplasticity and the transfer from music to language.

Studies with young adults have found similar transfer effects. Cooper and Wang (2012) had non-Cantonese speaking musicians and non-musicians learn Cantonese tones and found that musical experience improved musicians' performance in discriminating Cantonese words, with musicians showing significantly higher accuracy after training. Dittinger et al. (2016) combined behavioral and EEG techniques to examine the effect of musical experience on word learning in adolescents. Behavioral results showed that musicians had shorter reaction times and higher accuracy in word-picture association tasks compared to non-musicians. Electrophysiological results revealed that while both groups showed N400 in frontal regions under semantic mismatch conditions, only musicians showed N400 distribution shifting from frontal to parietal regions—similar to known words—indicating that only musicians integrated new words into established semantic networks. Follow-up testing five months later showed that musical experience enhanced long-term memory, with musicians recalling significantly more words accurately.

Dittinger et al. (2019) extended this research to older adults to explore musical experience effects on new word learning across the lifespan. Results showed that while older adults could still learn new words due to neural plasticity, the clear effects of musical experience on second language word learning observed in younger populations were not found, suggesting that aging weakens the transfer effects of musical experience, possibly due to decline in corresponding brain functions. Moreover, the benefits of musical experience for episodic memory of new words and integration into semantic networks appeared only in children and young adults.

In syntactic learning, research has not yet covered different developmental stages as comprehensively as vocabulary learning, but studies with children and adolescents have provided evidence for musical experience promoting second language processing. Ludke (2018) randomly assigned 12-13-year-old English native speakers to music groups or visual arts and drama groups for six weeks of French instruction. Both groups showed significant improvement in sentence construction ability after six weeks, but the music group showed greater gains. Busse et al. (2021) also divided German primary school children into singing and speaking groups for English grammar instruction and found that after five lessons, the singing group performed better on grammar tests, demonstrating the facilitative effect of musical experience on second language syntactic learning.

Overall, increasing research provides empirical evidence for the benefits of musical experience in second language learning. Current studies suggest that musical experience better facilitates second language learning in children and young

adults, while this cross-domain transfer effect is difficult to observe in older populations. However, existing research has focused mainly on children and adolescents, with few studies exploring how early musical experience affects second language learning in adults of different ages. As second language learning is a dynamic cognitive process across the lifespan, research with different age groups will help reveal the mechanisms of musical transfer effects on language learning more deeply.

4. Underlying Mechanisms of Musical Experience Effects on Second Language Processing

The above studies examined how musical experience affects second language processing in comprehension, production, and learning. What are the underlying mechanisms of these effects, and what commonalities and differences exist across these three domains? Currently, two main hypotheses explain how musical experience facilitates language processing. The first hypothesis suggests that musical experience promotes processing of acoustic cues shared by music and language, thereby facilitating language processing. The second hypothesis proposes that musical experience enhances general cognitive processing abilities, particularly auditory attention and auditory working memory, thereby improving language processing. Building on these, the OPERA hypothesis combines both, analyzing the internal mechanisms through which musical experience affects language processing: music and language share some sound and cognitive processing pathways and neural networks in the brain. Because music requires more precise sound and cognitive processing than language, repeated musical learning, combined with evoked positive emotions and attention, ultimately enhances language processing ability.

The first hypothesis has received support from studies on second language processing. In second language comprehension, researchers presented English syllable stimuli to English native speakers, French native musicians, and French native non-musicians while collecting EEG signals. They found that French musicians showed neural responses to formant frequencies similar to English native speakers, suggesting that musical experience enhances musicians'subcortical neural encoding of acoustic information during second language perception, compensating for limited language-specific experience. In second language production, researchers tested English native speakers on Spanish pronunciation and found that musical experience primarily affected pitch perception ability related to auditory processing, rather than working memory, leading to better second language imitation ability. In second language learning, researchers observed that musical experience facilitated vocabulary learning accuracy when participants learned pseudowords with tonal features different from their native language, suggesting this may be due to musical experience promoting shared general auditory processing abilities between music and language. Subsequent studies verified this facilitation of auditory cortical information processing through oddball tasks and assessments of EEG signal complexity before and after musical

training.

Other studies provide evidence that musical experience facilitates second language processing by enhancing general cognitive processing abilities. Musical experience mainly improves musicians' attention and working memory abilities, thereby facilitating second language processing. In second language comprehension, musical experience helps strengthen automatic brain responses during second language reading, helping individuals better overcome native language constraints to integrate visual and auditory information. Studies comparing EEG results of musicians and non-musicians under different audiovisual conditions found that musicians showed stronger theta oscillations, indicating their habit of top-down regulation during perception. In second language learning, studies with children from different countries learning English have found that singing, compared to traditional speaking methods, leads to faster vocabulary growth and higher sentence translation accuracy. Researchers suggest that this interesting artistic form can attract children' s interest and improve attention, thereby promoting better allocation of cognitive resources for learning second language vocabulary and syntax.

Current research has mainly found commonalities in the mechanisms through which musical experience affects second language comprehension, production, and learning. Whether differences exist requires further exploration combining the distinct characteristics of these three cognitive processes. For example, studies have found that musical experience affects second language perceptual comprehension ability by enhancing working memory, while another study found that musical experience affects second language production mainly through pitch perception ability rather than working memory. Although both studies assessed participants' working memory, differences in paradigms used to examine specific language abilities may contribute to these different mechanisms. The naming speed paradigm used to examine comprehension involves rapid retrieval of temporarily stored information, while the reading aloud task used to assess production does not heavily involve memory abilities. Therefore, future research should compare the role of working memory in both transfer effects under more rigorous experimental designs or explore this from a causal perspective to further reveal differences in mechanisms between musical facilitation of second language comprehension and production. In vocabulary learning, episodic and semantic memory must be engaged to build new phonological representations associated with new word meanings. Dittinger et al. (2021) found that musical experience facilitates second language vocabulary learning through enhanced long-term memory, extending the mechanism of general cognitive ability enhancement to a new domain. Whether this mechanism also operates in second language comprehension and production remains to be answered. Furthermore, previous researchers have often studied language comprehension and production independently; a comparative perspective examining differences in mechanisms would be valuable for understanding language processing and the relationship between music and language.

5. Summary and Future Directions

Existing research using different experimental paradigms and techniques has found positive effects of musical experience on second language processing, which is crucial for understanding the relationship between music and language and for promoting the application of music education in second language learning. Nevertheless, many questions remain to be explored.

First, research on musical experience facilitating second language processing can be further developed from linguistic, musical, and participant perspectives. From a linguistic perspective, most existing research has focused on language comprehension, with fewer studies on second language production and learning. Moreover, research has almost exclusively examined word or sentence processing, with little empirical evidence on whether second language processing at higher discourse levels also benefits from musical experience. From a musical perspective, assessment of musical experience has often relied on self-reported years of training. More careful assessment should consider other factors such as richness of childhood musical environment, including number of family CDs, family members who play instruments, and frequency of concert attendance. Additionally, individual personality differences may moderate musical experience by affecting motivation and persistence in musical learning. From a participant perspective, most studies have examined effects of musical experience on second language processing in typical populations. What role does musical experience play for populations with language processing disorders, and what types of musical experience are most effective for treating specific language disorders? Exploring these questions would not only deepen understanding of the mechanisms through which musical ability facilitates second language processing but also promote the practical application of music in language learning and language disorder remediation.

Second, does the influence of musical experience on second language processing stem entirely from acquired musical experience, or does innate musical aptitude also play a role? Most existing research has compared musicians and non-musicians cross-sectionally or conducted longitudinal tracking of participants without musical experience before and after short-term training, finding facilitative effects of musical experience. Notably, both approaches have overlooked the confounding effect of musical aptitude, making it difficult to isolate pure musical experience effects. Although limited in number, some studies have selected individuals without formal musical training and classified them as high-aptitude or low-aptitude groups based on musical aptitude tests, finding effects of musical aptitude on second language comprehension and production. Mankel and Bidelman (2018) compared the roles of innate musical aptitude and acquired musical experience in speech processing. They compared musicians, high-aptitude non-musicians, and low-aptitude non-musicians on speech processing tasks in quiet and noisy conditions. FFR and ERP results showed that in quiet conditions, listeners with musical experience showed better speech discrimination than those without. However, in noisy conditions, individuals with naturally more sensi-

tive hearing who had not received formal musical training could demonstrate language processing similar to musicians. Thus, musical experience and musical aptitude jointly shape neural encoding of speech. Future research could use longitudinal tracking to compare second language processing performance before and after musical training in individuals with different musical aptitudes, clarifying the respective contributions and mechanisms of innate aptitude versus acquired training, thereby advancing understanding of the essential relationship between music and language.

Finally, what are the connections and distinctions between the effects and mechanisms of musical experience on second language versus native language processing? In terms of connections, some effects of musical experience on native language processing also appear in second language processing. For example, musical experience improves musicians' native language pitch discrimination and tone processing, and they show similar transfer effects in second language contexts. However, some studies have found different effects of musical experience on native versus second language processing. Some research found stronger facilitative effects on native language processing, while others found stronger advantages in second language comprehension among Chinese elementary students. These different effects suggest that musical experience' s facilitative role may be moderated by language familiarity. Future research could further compare native and second language processing in production and learning domains and explore the underlying mechanisms. When comparing effects on native and second language processing, researchers should consider specific characteristics of the languages involved, design appropriate experimental materials and tasks to avoid ceiling effects in native language processing and floor effects in second language processing. Additionally, participant age should be considered, as older children and adults have more stable native language abilities, making musical experience effects more likely to emerge in second language processing.

In conclusion, musical experience influences second language comprehension, production, and learning. It can improve second language perception and lexical comprehension, facilitate second language imitation and pronunciation, and help vocabulary and syntax learning across different age groups. The cross-domain transfer effect has been preliminarily explained through two mechanisms: promoting shared acoustic cue processing and enhancing general cognitive abilities. Future research should further explore these mechanisms, particularly potential differences across comprehension, production, and learning domains. Investigating the relationship between musical experience and second language processing will not only advance theoretical understanding of music-language relationships but also have practical value in education and clinical applications.

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